Review of Unit 2: Freefalls, Forces and Accceleration

- **Acceleration:** the rate of change of velocity.

- **Instantaneous vs average acceleration:**

Instantaneous acceleration is the acceleration at a particular time.

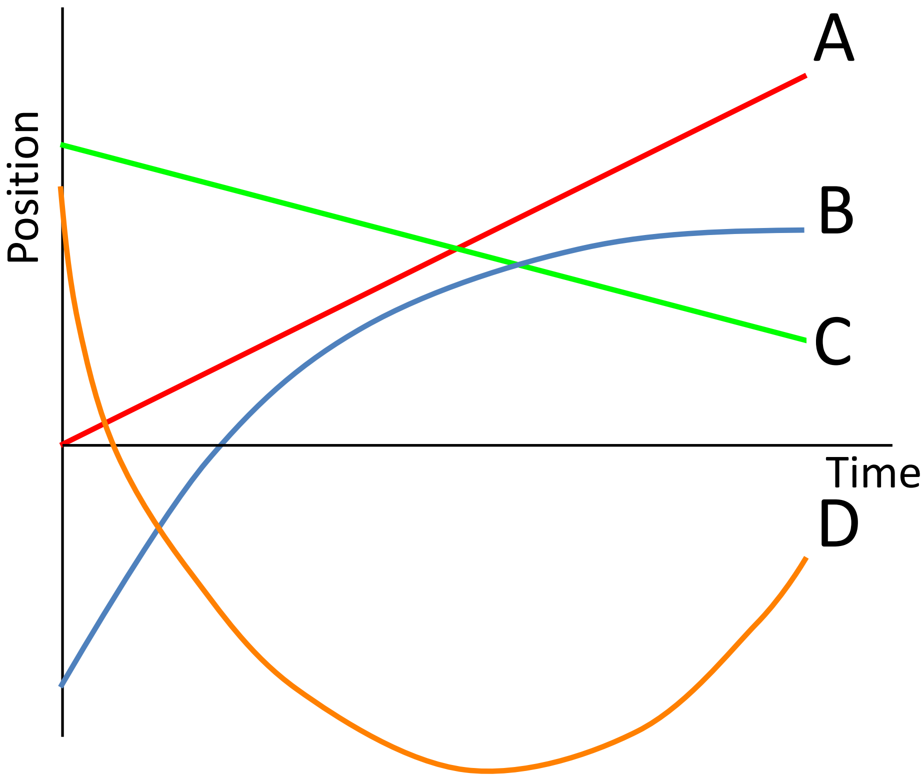
Mathematically, $$a = \frac{dv}{dt}$$

Or in terms of the position, $$a = \frac{d^2x}{dt^2}$$

Average acceleration is the average value of acceleration over a certain period.

Mathematically, $$a_{ave} = \frac{\Delta v}{\Delta t}$$

Consider the position-time graph shown below. Which one best describes a motion with a constant positive acceleration?



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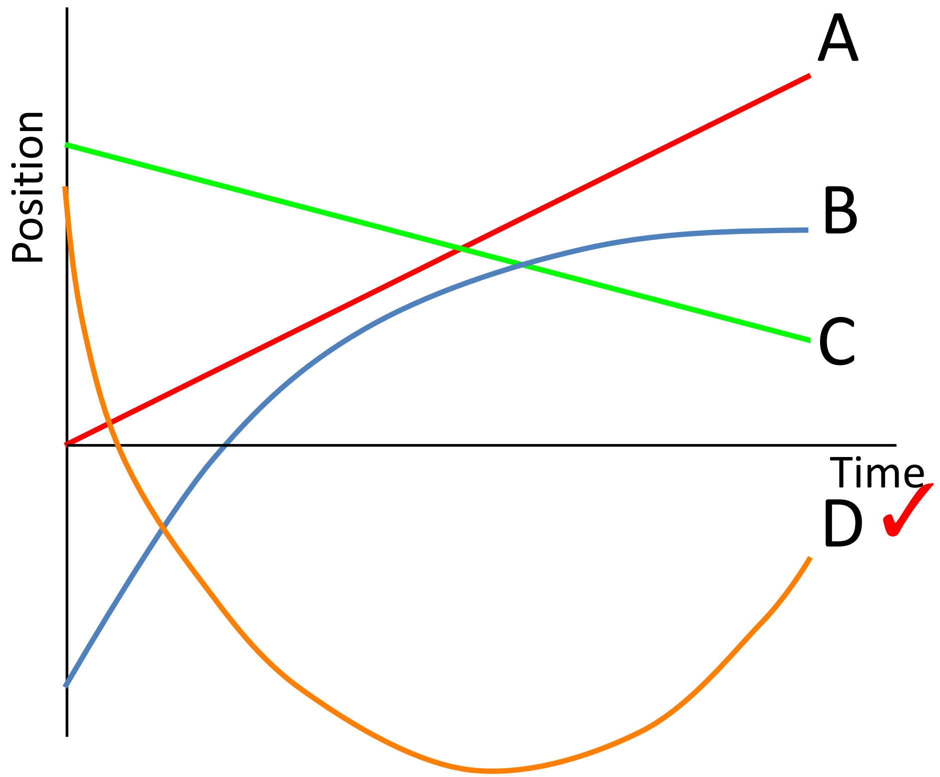

Review of Unit 2: Freefalls, Forces and Accceleration

- **Freefall:** motion of an object under the action of gravity alone is a motion with a constant acceleration with

$$a = -g \qquad \text{where} \qquad g = 9.8\ m/s^2 \approx 10\ m/s^2$$

Note: Here, we assume the downward direction to be negative. If we assume the downward direction to be positive, then $a = +g$.

Suppose you throw a bean bag directly upward (in the positive direction).

What can you conclude about its velocity and acceleration when it reaches the maximum height?

A. $v = 0, a = 0$

B. $v = 0, a > 0$

C. $v = 0, a < 0$

D. $v > 0, a = 0$

E. $v < 0, a = 0$

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Review of Unit 3: Newton's Second Law

- **Newton's Second Law:** the net force acting on an object equals the product of its mass times its acceleration:

$$\boxed{F = ma}$$

Alternatively, $$\sum F = ma$$

Emphasizing that the left-hand side of the equation means the sum of all forces acting on the object

- Different types of forces result in different types of motion.
- We can determine the motion by using Newton's second law and examining how the force depends (or does not depend) on position and velocity.

Review of Unit 3: Newton's Second Law

- **Force law 1:** force is zero.

$$F = 0 \quad \Longrightarrow \quad a = 0$$

$$v = v_0$$ Motion with a constant velocity.

$$x = v_0 t + x_0$$ Position-time graph is linear.

- **Newton's First Law:** If no net force acts on an object, then its velocity is constant.

Review of Unit 3: Newton's Second Law

- **Force law 2:** force is constant.

$$F = \text{constant} \quad \Longrightarrow \quad a = \text{constant}$$

$$v = at + v_0$$ Velocity-time graph is linear.

$$x = \frac{1}{2}at^2 + v_0 t + x_0$$

Position-time graph is parabolic.

- **Example 1:** force of gravity

$$F = -mg \quad \Longrightarrow \quad a = -g$$

- **Example 2:** force of sliding (kinetic) friction

$$F = -\mu F_{normal}$$

$\mu =$ coefficient of (kinetic) friction

$F_{normal} =$ force pushing two surfaces together

minus sign emphasizes that the force opposes motion.

Important: For friction, position-time graph is not completely parabolic.

Review of Unit 3: Newton's Second Law

- **Force law 3: spring force law (Hooke's law)**, force is proportional to position with a negative proportionality constant.

$$F = -kx \quad \Longrightarrow \quad x, v, a \text{ are all sinusoidal in time.}$$

$k =$ spring constant

Note: x, v, a cannot all be the same sinusoidal function.
For example, if x is sin, v is cos, and a is −sin.

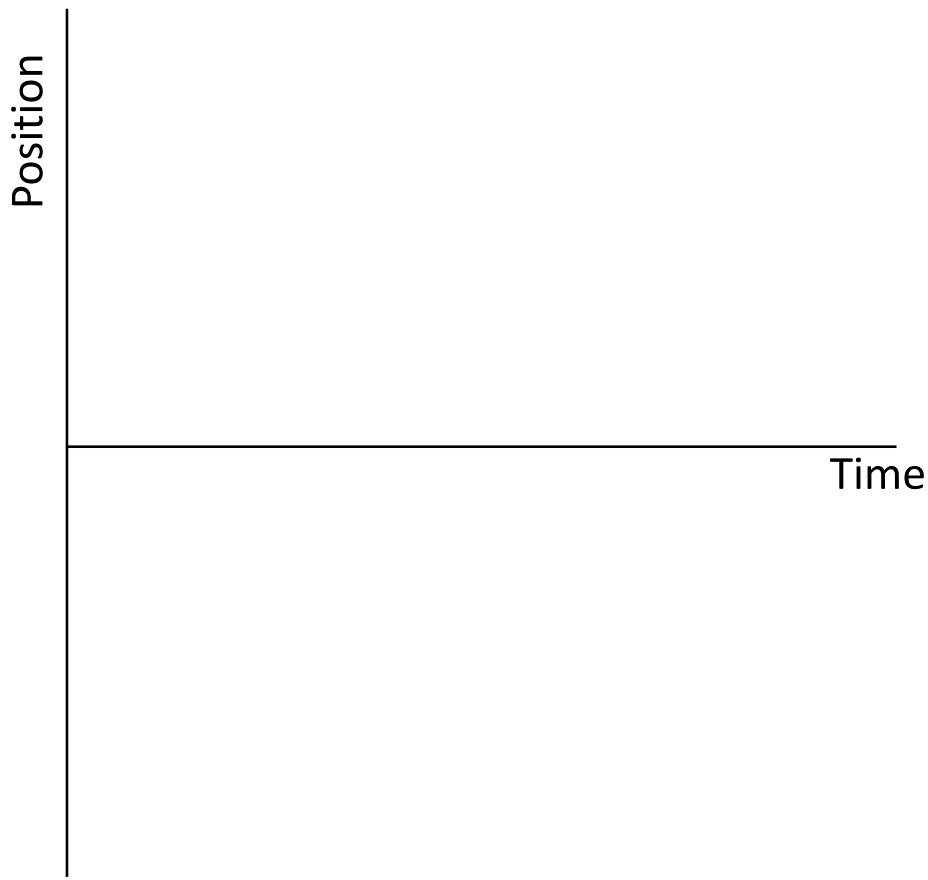
- **Force law 4: drag force**, force is proportional to velocity.

$$F = -\alpha v \quad \Longrightarrow \quad v \text{ decreases exponentially with time.}$$

- These four are just some of the simplest force laws. There are other more complicated laws.

Suppose $F = -\alpha v$

Sketch a possible position-time graph with a negative initial position and a negative initial velocity.



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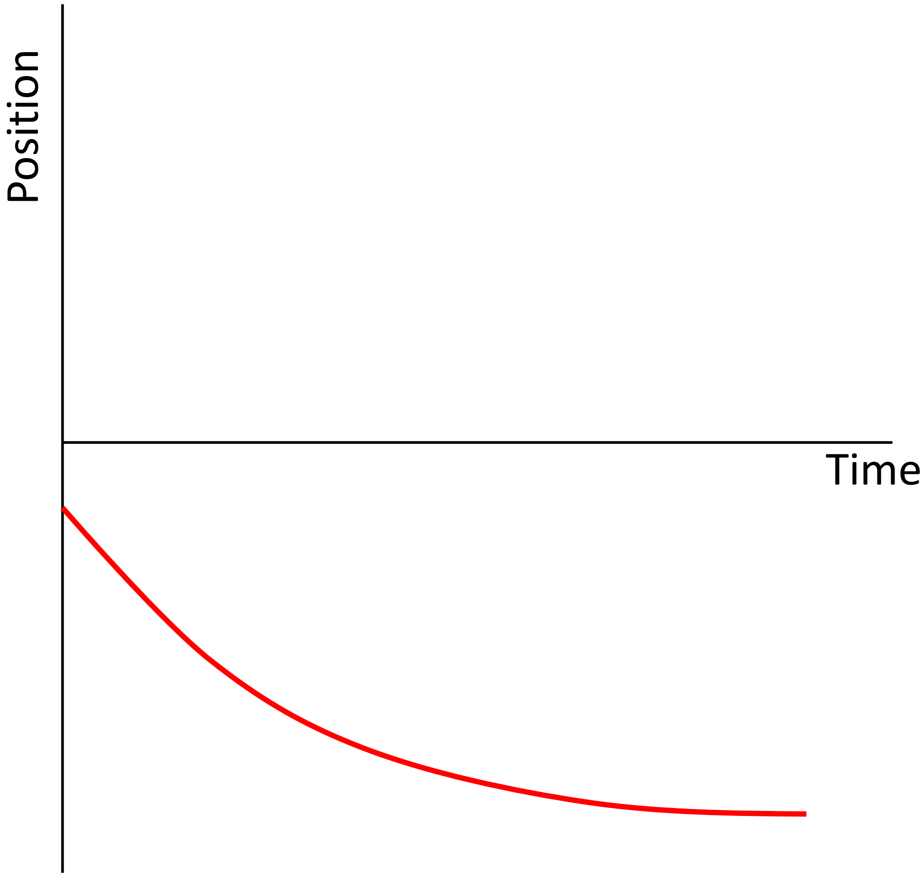

Suppose $F = -kx - \alpha v$

Sketch a possible position-time graph.

Suppose $F = -kx - \alpha v$

Sketch a possible position-time graph.